Table of Contents

Chapter 1 - Introduction

1.1 Introduction ..... - 1 -
1.2 Definition of terms ..... - 1 -
1.3 Background ..... - 1 -
1.4 Goal statement ..... - 1 -
1.5 Objectives ..... - 2 -
1.6 Project management technique ..... - 2 -
1.7 Stages of development ..... - 2 -
1.8 Work plan ..... - 3 -
1.9 Technologies overview ..... - 3 -

Chapter 2 - User requirements and analysis

2.1 Introduction ..... - 5 -
2.2 Background ..... - 5 -
2.2.1 Current procedure ..... - 5 -
2.2.2 Current problems ..... - 6 -
2.2.3 The users ..... - 7 -
2.3 User requirements ..... - 7 -
2.3.1 Desired working practice ..... - 7 -
2.3.2 Requirements capture ..... - 8 -
2.3.3 Users requirements ..... - 9 -
2.3.4 Differing user requirements ..... - 10 -

Chapter 3 - Specification and design

3.1 Introduction ..... - 11 -
3.2 Research ..... - 11 -
3.2.1 Automated Deployment Services (ADS) vs. Remote Installation Services (RIS) features ..... - 11 -
3.2.2 ADS vs. Novell ZENworkes 6 and Altiris SPS ..... - 12 -
3.2.3 Speed of deployment ..... - 13 -
3.2.4 Cost of deployment ..... - 13 -
3.2.5 Advantages of C# ..... - 13 -
3.2.6 Advantages of Visual Studio ..... - 14 -
3.2.7 Other project tools ..... - 14 -
3.3 Risk assessment summery ..... - 14 -

Chapter 4 - Research and risk assessment

4.1 Introduction ..... - 15 -
4.2 Specification ..... - 15 -
4.2.1 Functional specification ..... - 15 -
4.2.2 Non-functional specification ..... - 16 -
4.3 Website design ..... - 17 -
4.3.1 HCI principles ..... - 17 -
4.3.2 Design choice and justification ..... - 19 -
4.4 Data modelling ..... - 21 -
4.4.1 Current database ..... - 21 -
4.4.2 Identify entities and attributes ..... - 21 -

4.5 Entity relationship identification ..... - 23 -
4.6 Normalization ..... - 25 -
4.7 Data Dictionary ..... - 26 -

Chapter 5 - Implementation

5.1 Introduction ..... - 29 -
5.2 Website map ..... - 29 -
5.3 Database creation ..... - 30 -
5.4 Login page ..... - 30 -
5.5 Left Navigation page ..... - 31 -
5.6 Home page ..... - 31 -
5.7 Configuration page ..... - 32 -
5.7.1 Loading of a configuration ..... - 32 -
5.7.2 Saving of a Configuration ..... - 33 -
5.7.3 Applying a configuration ..... - 35 -
5.8 View configuration pages ..... - 38 -
5.9 Administration page ..... - 39 -
5.10 Manage users, tasks and computers pages ..... - 39 -
5.11 Statistics page ..... - 40 -
5.12 Style sheet ..... - 40 -

Chapter 6 - Testing and evaluation

6.1 Introduction ..... - 41 -
6.2 Testing outline ..... - 41 -
6.2.1 Unit testing outline ..... - 41 -
6.2.2 Integration testing outline ..... - 41 -
6.2.3 Acceptance testing outline ..... - 42 -
6.3 Unit testing ..... - 42 -
6.4 Integration testing ..... - 43 -
6.4.1 Test cases ..... - 43 -
6.4.2 Security testing ..... - 43 -
6.5 Acceptance testing ..... - 44 -
6.5.1 Usability testing ..... - 44 -
6.5.2 System testing ..... - 44 -
6.5.3 Functional testing ..... - 45 -
6.6 Evaluation and testing summery ..... - 46 -

Chapter 7 - Conclusion and future developments

7.1 Introduction ..... - 47 -
7.2 Project summary ..... - 47 -
7.3 Critique ..... - 47 -
7.4 Project extensions ..... - 48 -
7.5 Conclusion ..... - 49 -

References and bibliography ..... - 50 -
Appendix ..... - 54 -
User Manual ..... -154 -

List of Tables

Table 1.1: Terms used throughout the report	- 1 -
Table 1.2: Project objectives	- 2 -
Table 2.1: Advantages and Disadvantages of RIS	- 5 -
Table 2.2: Advantages and Disadvantages of ADS	- 6 -
Table 2.3: ILS problems generalised	- 6 -
Table 2.4: Identified users of the website	- 7 -
Table 2.5: Advantages and Disadvantages of new website	- 7 -
Table 2.6: Users primary requirements	- 9 -
Table 2.7: Users secondary requirements	- 9 -
Table 3.1: Difference of ADS and RIS	- 11 -
Table 3.2: Benefits of C#	- 13 -
Table 3.3: Benefits of Visual Studio	- 14 -
Table 3.4: Other project tools	- 14 -
Table 4.1: Functional specification	- 15 -
Table 4.2: Non-functional specification	- 16 -
Table 4.3: Semiotics in use	- 17 -
Table 4.4: Websites defensive design methods	- 18 -
Table 4.5: Web pages security methods	- 18 -
Table 4.6: Colours used on the website	- 19 -
Table 4.7: Identified database entities	- 21 -
Table 4.8: Extended entities from current ADS	- 21 -
Table 4.9: Description of relationship terms	- 23 -
Table 4.10: Final USER table	- 26 -
Table 4.11: Final TASK table	- 27 -
Table 4.12: Final COMPUTER table	- 27 -
Table 4.13: Final JOB table	- 28 -
Table 4.14: Final CONFIGURATION table	- 28 -
Table 4.15: Final JOBTASK table	- 28 -
Table 4.16: Final CONFIGURATIONJOB table	- 28 -
Table 5.1: Steps taken to load a configuration	- 33 -
Table 5.2: Steps taken to save a configuration	- 34 -
Table 5.3: Step taken to apply a configuration	- 36 -
Table 5.4: User attribute row numbers	- 39 -
Table 6.1: Types of unit testing performed on the website	- 41 -
Table 6.2: Types of integration testing performed on the website	- 41 -
Table 6.3: Types of acceptance testing performed on the website	- 42 -
Table 6.4: Web pages that passed all unit tests	- 42 -
Table 6.5: Web pages that did not pass all unit tests	- 42 -
Table 6.6: Levels of page security	- 43 -
Table 6.7: Security levels of the web pages	- 43 -
Table 6.8: How well the user requirements were met	- 44 -
Table 6.9: How well the functional specification was met	- 45 -
Table 6.10: How well the non-functional specification was met	- 45 -

List of Figures

Figure 3.1: Deployment system scores	- 12 -
Figure 3.2: Deployment system features	- 12 -
Figure 4.1: Defensive design	- 18 -
Figure 4.2: Screenshot of Microsoft's website	- 20 -
Figure 4.3: New task hierarchy using extended entities	- 22 -
Figure 4.4: USER and JOB relationship	- 24 -
Figure 4.5: USER and CONFIGURATION relationship	- 24 -
Figure 4.6: CONFIGURATION and JOB relationship	- 24 -
Figure 4.7: JOB and TASK relationship	- 24 -
Figure 4.8: JOB and COMPUTER relationship	- 24 -
Figure 4.9: Complete entity relationship diagram	- 25 -
Figure 4.10: JOBTASK discovered entity	- 25 -
Figure 4.11: CONFIGURATIONJOB discovered entity	- 25 -
Figure 4.12: Final entity relationship diagram	- 26 -
Figure 4.13: ADS and website database link	- 27 -
Figure 5.1: Website map	- 29 -
Figure 5.2: Joining of XML tasks	- 35 -
Figure 5.3: Flow diagram for applying a configuration	- 37 -
Figure 7.1: Linear and non-linear configurations	- 48 -

List of Extracts

Extract 5.1: Code to create a connection to the website database	- 30 -
Extract 5.2: Data being formatted as a SQL data type	- 30 -
Extract 5.3: Method to retrieve user information	- 31 -
Extract 5.4: SQL statement joining database tables	- 32 -
Extract 5.5: Code to check the user's privileges	- 38 -

Chapter 1
Introduction

1.1 Introduction
This project is concerned with assisting data centre workers and system administrators with the modelling, maintenance and deployment of data centre servers and desktop machines. The system produced will help technicians to quickly and easily analyse the current setup of their computers, and return those computers back to their original state or allow the installation of additional software remotely. This functionally will reduce the amount of time they must spend maintaining computer systems and the amount of time it will take them to return their systems to an operational state following a catastrophic event.

1.2 Definition of terms
To help clarify the subjects of discussion in this report, the terms in Table 1.1 will be used consistently throughout. A Glossary of Terms can also be found in Appendix 1.1

ILS Team	Members of staff working for the Microsoft UK Infrastructure and Laboratory Support (ILS) team
Computer	Refers to any desktop or server computer system
User	Any person who uses the website
Customer	A person who is paying for the use of the ILS labs
Technician	A person who is responsible for the computers' maintenance, including data centre workers and system administrators

Table 1.1: Terms used throughout the report

1.3 Background
This project is a result of an investigation into the working practices of the Infrastructure and Laboratory Support (ILS) team at Microsoft UK. The ILS team is responsible for the deployment and maintenance of an 800-machine computer laboratory. The Laboratory is used by internal and external customers for testing purposes, typically for a one or two week period. During their daily work the ILS team must ensure that customers' machines have the correct software installed and must build specific system setups for them.

This project found the current problems facing Microsoft ILS team and produced a suitable solution to solve these problems. In addition to a computer program this project includes research into new technologies, procedures and new working practices.

1.4 Goal statement
To deliver a system that will allow technicians to easily maintain and model their computer data centres, and allow them to quickly and easily rebuild their data centre from a bare bones situation.

1.5 Objectives

To help successfully achieve the goal of this project a set of objectives was created, shown in Table 1.2.

Objectives
Find the current main problems facing data centre workers and system administrators
Research the technologies and feasibility of a solution
Design and Develop a system to solve the discovered problems
Test the system for stability, reliability and usability
Evaluate the system against the original discovered problems
Produce complete documentation for the system

Table 1.2: Project objectives

1.6 Project management technique

As creating any piece of software requires planning to produce a high quality and functional piece of software that meets the users' requirements, this project will follow the V process model, shown in Appendix 1.3.

The V process model originally derived from the classic waterfall model for software project management, shown in Appendix 1.4. This model ensures that each stage of the project is completed successfully, and allows the flexibility to go back and change prior parts of the project if new information is discovered later on. It also helps with the testing of software as it shows what testing should be done at each stage to best meet the users' requirements.
(Dawson, 2004)

The V process model fits this project well due to the research and learning that was required. As new information was discovered during the research stage, the final solution better fitted the users' needs as this information was used as part of the solution. For these reasons the V process model was chosen over the waterfall model.

1.7 Stages of development

As with any large project time must be managed well, to ensure efficient time management the project was split into the following sections.

- **Introduction and planning stage** – a brief introduction about the project and the initial work plan.

- **Requirements and research** - concerned with the users' requirements for the system and research into technologies and techniques used in the solution.

- **Specification and design** - concerned with converting the users' requirements and suggestions into a formal specification, and designing a solution by combining the specification with the results of the research. This includes the design of database tables, entity relationship diagrams, data

flow diagrams, sample user interface designs and trade offs that were made at the design stage.

- **Implementation and testing** - is concerned with the programming and creation of additional files needed in order for the proposed system to work and the trade offs that had to be made during the creation of the system.

- **Testing and evaluation** - concerned with how the system meets the users' requirements, and how well it matched the original specification. In addition to the trade offs that were included in the design and implementation part of the project, this section covers additional trade offs made. The testing ensured the stability, functionality and usability of the system.

- **Conclusion and further developments** - discuss problems encountered during the project and the over all effectiveness of the project and possible future developments for the system

1.8 Work plan

To help the time management of the project a Gantt chart was produced to give a time frame for each section of the project, shown in Appendix 1.5, a revised and easier to read Gantt chart was also produced, shown in Appendix 1.6. This gave a clear indication of when each section of the project needed to be completed to finish the project on time.

1.9 Technologies overview

The following are brief overviews of the technologies used in this project.

Microsoft Automated Deployment Services (ADS)

Microsoft Automated Deployment Services (ADS) is a new Microsoft service that runs on Microsoft Windows Server 2003 Enterprise Edition to aid with the deployment of Microsoft server operating systems. ADS can be used in data centres to deploy software and to manage computers. ADS works by using the Pre-boot eXecutable Environment (PXE) to allow control of computers prior to the Operating System (OS) loading (pre-OS), and a small program called the 'Administration Agent' (AA) to control them post-OS. Further information on ADS is covered in Appendix A1.2.
(Microsoft, 2005)

.NET

"Microsoft® .NET is a set of new software technologies for connecting information, people, systems, and devices which is based on Web services—small building-block applications that can connect to each other as well as to other, larger applications over the Internet."
(Microsoft, 2005)

.NET is a Microsoft system that allows applications to easily communicate with each other by using .NET technologies. This usually consists of using a .NET programming language such as C#.net, VB.net or J#.net and using eXtensible Markup Language (XML) as a common information transportation language.

Windows Management Instrumentation (WMI)
"Windows Management Instrumentation (WMI) is a component of the Microsoft Windows operating system and is the Microsoft implementation of Web-Based Enterprise Management (WBEM), which is an industry initiative to develop a standard technology for accessing management information in an enterprise environment. WMI uses the Common Information Model (CIM) industry standard to represent systems, applications, networks, devices, and other managed components. You can use WMI to automate administrative tasks in an enterprise environment."
(Microsoft, 2005)

WMI can be thought of, on the most basic level, as an interface standard that allows applications to programmatically access each others functionality and information. This allows applications to send and receive information to each other easily, without the programmer having to worry about the format in which the information should be sent. The last sentence of Microsoft's description is very apt as this project is concerned with this area.

Chapter 2
User requirements and analysis

2.1 Introduction

This chapter covers the identification of the problems that forms the basis of this project, requirements of the potential users of the website and current and new work procedures.

2.2 Background

As described in the first chapter, this project is a result of an investigation into the working practices of the Infrastructure and Laboratory support (ILS) team at Microsoft UK. The following section is further background information.

2.2.1 Current procedure

To help the ILS team do their job they currently have a Microsoft Remote Installation Services (RIS) server running in the lab. More information on RIS can be found in Appendix A2.1.

As RIS is a 'pull' deployment system, the laboratory technician must manually go to each computer that requires a new OS to be installed and manually reboot it. Once the OS has been installed, the technician must perform any post-OS configuration required on each computer separately

The current work process that the ILS team uses is shown in Appendix 2.2 and the times for each of these steps can be found in appendix A2.3. This process has six steps that require interaction from the technician and requires on average a total of 5.7 minutes of their time, shown in Appendix 2.4. The total average time taken to install an OS for one computer is 41.3 minutes.

Table 2.1 shows the advantages and disadvantages of the current system that the ILS team have in place and Table 2.2 shows the advantages and disadvantages of the system if the RIS server was changed to an ADS server (without additional website functionality).

Advantage	Faster than using CD
Advantage	Standardised installations
Disadvantage	Still takes a long time to install operating system
Disadvantage	Requires lots technician interaction
Disadvantage	Can only install single instances
Disadvantage	Cannot install applications
Disadvantage	Customers cannot start installation instances
Disadvantage	Does not understand infrastructure hierarchy

Table 2.1: Advantages and Disadvantages of RIS

Advantage	Faster than using RIS
Advantage	Standardised installs
Advantage	Single point of administration
Advantage	Can install applications
Disadvantage	Customers cannot start installation instances
Disadvantage	Does not understand infrastructure hierarchy
Disadvantage	Job will not continue if one step fails
Disadvantage	Potential security risks
Disadvantage	Does not understand infrastructure hierarchy

Table 2.2: Advantages and Disadvantages of ADS

Although changing the RIS server for an ADS server would introduce benefits for the ILS team, there would still be a number of disadvantages present.

The management team for ILS do not currently have an automated system for calculating the statistics about software usage; they rely on asking the technicians what they have installed. This is not only time consuming for both the management and the technicians but is also not a very accurate way of collecting the data.

2.2.2 Current problems

The main problems that face the ILS team are the design and deployment time of complete systems. On average, a customer will ask for around 40 computers that may all have their own unique configuration of software and hardware. This leads to a problem with the system design, as RIS does not have the ability to store a list of which OSs have been installed on each computer. Therefore the technician must ensure that records are kept. Deployment time is also an issue, as the technician has to wait for the current customers to leave on Friday before reconfiguring the computers for the new customers arriving on Monday morning.

Although these are problems specific to the ILS team at Microsoft, they can be generalised to apply to any organisation that has computers, shown in Table 2.3

Problem	**Description**
System design	This is a problem in any organisation, as all the technicians need to know what software is on each computer so that they do not reformat the wrong one. In addition, as there may be many computing staff, there needs to be a record of what software is on each computer in case it needs to be rebuilt and the person who built it originally is not available.
Deployment time	This is becoming increasingly more important for companies as a high computer utilisation rate will increase profitability, for example e-commerce sites or online services. Additionally, following a virus or hacker attack, every minute that the computer system is down could be costing the company thousands of pounds in lost revenue, so restoring the computer system to its original state quickly is imperative to minimise losses.

Table 2.3: ILS problems generalised

2.2.3 The users

There are three main user groups identified that will use the website; these are shown in Table 2.4.

User Group	Description
Technical lab workers	The Microsoft ILS lab team will be the primary users of the website. The lab staff will use the website on a daily basis to install and configure software on computers in the Microsoft data centre.
Management	The ILS management will be the secondary users of the website. They will use the website to retrieve statistics about computer and software usage.
External Customers	Customers that come in to Microsoft to use the computers in the data centre will be the tertiary users of the website. They will use the website to examine their current configuration and request changes to it.

Table 2.4: Identified users of the website

2.3 User requirements

2.3.1 Desired working practice

As show in Appendix 2.2, the current working practice of the ILS team requires the technician to go to each computer that needs a software change, and manually perform any post-OS configuration on an individual basis.

The new working practice requested is for the technician to have much less interaction with each computer, and for the customer to be able to submit an electronic request as opposed to a verbal request. As new working practice, shown in Appendix 2.5, requires less interaction from the technician it will allow him/her to carry on with other work and also reduces the total amount of time taken for the customers' computers to be reconfigured.

Table 2.5 shows the advantages and disadvantages that the website will provide. This includes all of the benefits of using an ADS server but also addresses most of the disadvantages of the ADS system.

Advantage	Faster than using RIS
Advantage	Standardised installations
Advantage	Single point of administration
Advantage	Can install applications
Advantage	Customers can start installation instances
Advantage	Understand infrastructure hierarchy
Advantage	Job can be resumed if a step fails
Disadvantage	Potential security risks

Table 2.5: Advantages and Disadvantages of new website

2.3.2 Requirements capture

To best capture the requirements, potential users of the system were interviewed and asked to describe how they would want a deployment system to work and what features would be needed to accomplish this.

This methodology was chosen over a formal questionnaire due to the problem of the project being well understood and firsthand experience of using the present system. By using a written questionnaire it would have been extremely difficult to get the same level of detail that could be communicated verbally due to the complex nature of the project's solution. The e-mail responses provided a brief description of the features required without having to go into complex detail that was already known from the verbal interviews. A questionnaire would have only confirmed information that was already known to be true and would have contributed very little new information to the solution. The users' e-mail responses to features they would like on the website can be seen in Appendix A2.8.

A list of requirements was generated from the users' verbal and e-mail responses, this was e-mailed back to the users to see if the features described fully met their requirements. For the preliminary list, a feature was assumed to be a critical feature of the website when language such as, "I want to" and "it must", was used in the responses. A feature was assumed to be optional when language such as, "It would be nice to" was used.

A preliminary list of features can be seen in Appendix A2.9, the users' responses to the list can be seen in Appendix A2.10. A final list of the users' requirements was then created using the preliminary list and taking in to consideration the users' comments.

2.3.3 Users requirements

The final primary user requirements are shown in Table 2.6.

Requirement	Explanation
Ability to run ADS tasks remotely	Would allow a technician to be anywhere in the world and still allow them to run ADS tasks. This could come in useful if a member of staff is off sick, training or on holiday and they are needed to perform certain actions remotely
Ability to queue ADS tasks	Would allow a technician to select multiple tasks they wanted to run on a computer all at once, instead of to keep having to revisit the ADS server.
Ability to design full, multiple computer setups	Will help with the deployment and the tracking of customer systems
Ability to reapply saved computer setups	Will ensure that if a customer revisits the labs they can have exactly the same computer setup they previously had when they used the labs. This could also be a useful feature if the customer was also using ADS in their data center, as the whole system design can be exported to XML. The customer could rerun the tasks in their data centre with minimal modification and recreate the exact environment they were using in the labs
Ability to produce statistics on computer and software usage	Requested by management to assist with budget allocation and staff training. The statistics would be able to show the usage of the computers to indicate which computers are used most and which software is used most frequently, so that training on the most appropriate subject can be given to the technicians.
Must include security features	Should only allow selected users to have access to the website, and allow only certain users to run certain jobs on certain computers

Table 2.6: Users primary requirements

The final secondary user requirements are shown in Table 2.7.

Requirement
Better support for installing patches
Ability to backup data on computer systems for later redeployment
Ability for customers to use the website
Ability to resume tasks that terminated with errors
Ability to schedule a job to run at a certain time
Ability to configure applications via the website
To be alerted once the job was finished by e-mail or SMS
To work over multiple geographical sites

Table 2.7: Users secondary requirements

To decide which of the features were implementable, research was conducted and the technological limiting factors and the time limiting factors were taken into account. A further explanation of technological limiting and time limiting factors is described in Appendix A2.11.

2.3.4 Differing user requirements

The different potential users of the website had differing requirements that must be met. The technicians requested features that would reduce their work load and simplify computer system design. The management requested features that would allow them to produce usage statistics and reports for computers and software.

As the technicians will be the primary users of the website their requirements took precedence. Additionally, before any statistics can be produced for the management, the technicians have to be using the website. If the functionally required by the technicians' is not present then they will not use the website, so the functions to produce statistics for the management would be useless.

The needs of the external customers were the last to be met as the website could still be used as an infrastructure support system rather then a customer facing system. As previously stated, without the functionally required by the technicians' the customer would be entering a request into a website that will not produce any output.

Chapter 3
Research and risk assessment

3.1 Introduction

This chapter covers research into the technologies and risks associated with this project. This was completed as a better understanding of the technologies used in this project was needed to produce a functioning website and also to reduce the risk of the project failing.

3.2 Research

Research came from a number of sources including official websites, white papers, academic papers and books. There is a large amount of information on websites relating to many of the subjects covered by this research. Despite this, the use of websites other than official product websites for sources of information was avoided where possible, due to the high amount of inaccurate information present on websites.

Microsoft's Galen Hunt (2005) cited in Sutton 2003, estimates that up to 70% of a company's IT budget can be spent on server maintenance. With such a large percentage of a budget being spent on keeping current systems operational, any time or money saving measure could mean large a saving to a company. To help address this, numerous systems are available to aid with the deployment of operating systems and other software.

3.2.1 Automated Deployment Services (ADS) vs. Remote Installation Services (RIS) features

Both ADS and RIS are Microsoft products and both offer a different way to deploy software to computers. There are many differences between the two products, the most relevant differences to this project are listed in Table 3.1.

Feature	ADS	RIS
Programmatic extensibility	Yes	No
Initiation type	Push – deployment is initiated by a central server	Pull – deployment is initiated by the user on each individual computer
Deployment method	Multicast	Unicast

Table 3.1: Difference of ADS and RIS (Microsoft, 2003)

As ADS is programmatically extensible and RIS is not, ADS is the logical choice out of these two Microsoft technologies to extend. An extended system could be build around RIS, although this would consist of a complex system of automatically running scripts to perform the users' chosen actions. The initiation type is also a major consideration as RIS requires a technician to visit each of the computers that require a change. Eliminating this need is a major advantage to the technician and the website, as if the ADS sever is controlling the computers the system can

be more autonomous. Finally, the deployment method is advantageous in ADS as it can perform more simultaneous deployments at greater speeds because of the use of multicasting.

3.2.2 ADS vs. Novell ZENworkes 6 and Altiris SPS

In a product review by Harbaugh 2003, Microsoft ADS was judged not to be as good overall as ZENworkes 6 or SPS, due to a very low score for 'Interoperability', see Figure 3.1. This was because of a lack of features ADS has compared to its competitors, see Figure 3.2.

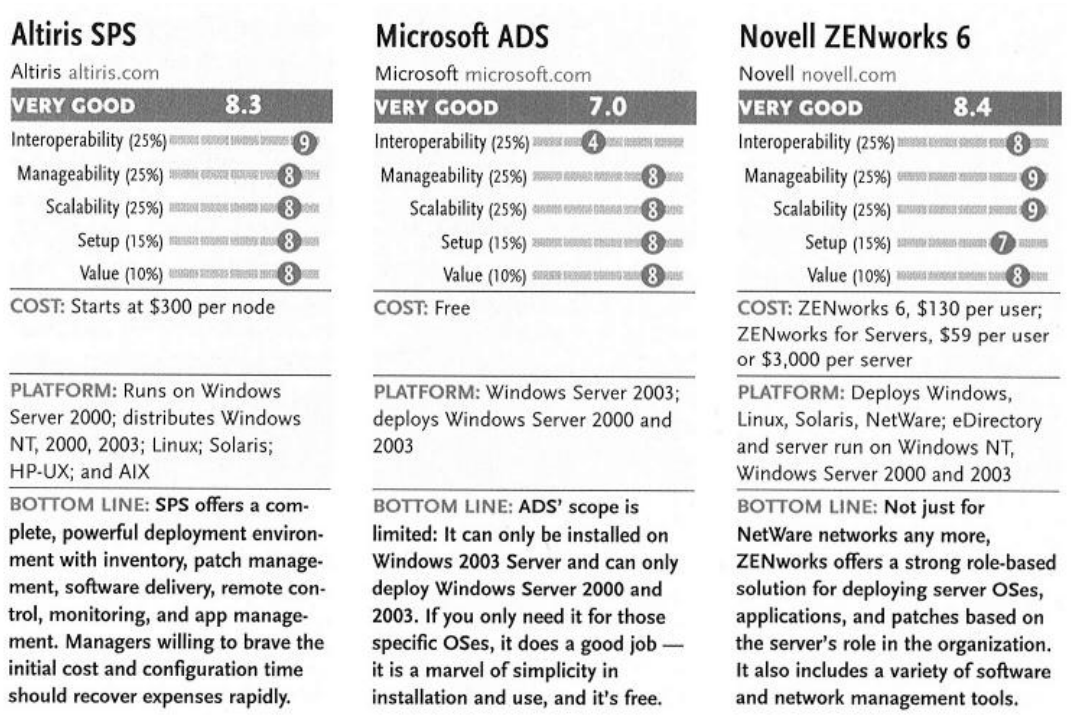
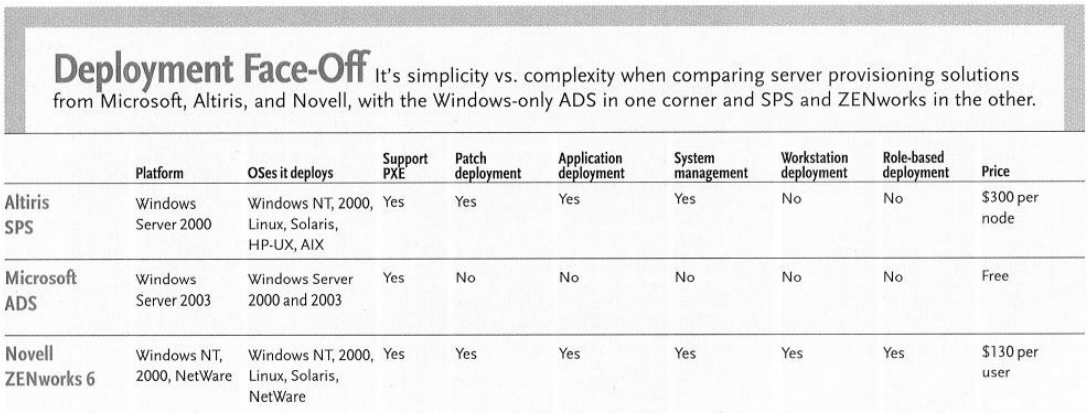

Altiris SPS
Altiris altiris.com
VERY GOOD 8.3
Interoperability (25%) 9
Manageability (25%) 8
Scalability (25%) 8
Setup (15%) 8
Value (10%) 8
COST: Starts at $300 per node
PLATFORM: Runs on Windows Server 2000; distributes Windows NT, 2000, 2003; Linux; Solaris; HP-UX; and AIX
BOTTOM LINE: SPS offers a complete, powerful deployment environment with inventory, patch management, software delivery, remote control, monitoring, and app management. Managers willing to brave the initial cost and configuration time should recover expenses rapidly.
Microsoft ADS
Microsoft microsoft.com
VERY GOOD 7.0
Interoperability (25%) 4
Manageability (25%) 8
Scalability (25%) 8
Setup (15%) 8
Value (10%) 8
COST: Free
PLATFORM: Windows Server 2003; deploys Windows Server 2000 and 2003
BOTTOM LINE: ADS' scope is limited: It can only be installed on Windows 2003 Server and can only deploy Windows Server 2000 and 2003. If you only need it for those specific OSes, it does a good job — it is a marvel of simplicity in installation and use, and it's free.
Novell ZENworks 6
Novell novell.com
VERY GOOD 8.4
Interoperability (25%) 8
Manageability (25%) 9
Scalability (25%) 9
Setup (15%) 7
Value (10%) 8
COST: ZENworks 6, $130 per user; ZENworks for Servers, $59 per user or $3,000 per server
PLATFORM: Deploys Windows, Linux, Solaris, NetWare; eDirectory and server run on Windows NT, Windows Server 2000 and 2003
BOTTOM LINE: Not just for NetWare networks any more, ZENworks offers a strong role-based solution for deploying server OSes, applications, and patches based on the server's role in the organization. It also includes a variety of software and network management tools.

Figure 3.1: Deployment system scores (Harbaugh, 2003)


Deployment Face-Off It's simplicity vs. complexity when comparing server provisioning solutions from Microsoft, Altiris, and Novell, with the Windows-only ADS in one corner and SPS and ZENworks in the other.

	Platform	OSes it deploys	Support PXE	Patch deployment	Application deployment	System management	Workstation deployment	Role-based deployment	Price
Altiris SPS	Windows Server 2000	Windows NT, 2000, Linux, Solaris, HP-UX, AIX	Yes	Yes	Yes	Yes	No	No	$300 per node
Microsoft ADS	Windows Server 2003	Windows Server 2000 and 2003	Yes	No	No	No	No	No	Free
Novell ZENworks 6	Windows NT, 2000, NetWare	Windows NT, 2000, Linux, Solaris, NetWare	Yes	Yes	Yes	Yes	Yes	Yes	$130 per user

Figure 3.2: Deployment system features (Harbaugh, 2003)

The website will to some extent extend the features of ADS to include patch deployment, application deployment, work station deployment and role-based deployment. With these extra features ADS would be a serious contender with its rivals on interoperability and still retain its free price tag.

As the Infrastructure and Laboratory Support (ILS) team can only use Microsoft products due to company policy, ADS and RIS are the only two options available to them. This could also be the case at other companies if they have licensing agreements with Microsoft or already own Windows Server 2003 and do not have the budget available to pay for ZENworkes or Altiris SPS.

3.2.3 Speed of deployment

ADS provides a large speed advantage over the current RIS system. This will allow customer computer setups to be deployed faster, this decreases response times to requests and gives the technicians more time to complete other work. A full discussion and justifications on deployment speed is given in Appendix 3.2.

3.2.4 Cost of deployment

Using an ADS server introduces a number of costs benefits over using a RIS server. As ADS requires less man hours per computer to create a customer's configuration money can be saved on staffing costs. A full discussion on other cost savings and a case study is shown in Appendix 3.3

3.2.5 Advantages of C#

C# was chosen as the language to create the website as the ILS team required a website that used Microsoft technologies to work. The website will be an ASP.Net page with C# code behind.

C# has a number of benefits; shown in Table 3.2.

Feature	**Benefit**
A strong C# community	Provides lots of tutorials, papers and code example
XML compatibility	Allows easy manipulation of XML files
Truly object orientated	Provides ease of use for the all program objects
Built in error handling	Helps capture user and data errors
Complied code	Provides faster runtime execution
Managed code	Helps to reduce unsafe code and exploits such as buffer overflows
Memory management and garbage collection	Ensures no memory leaks
Associated class library	Reduces the need to 'reinvent the wheel'

Table 3.2: Benefits of C# (Meyne & Davis, 2002 and Williams, 2002)

3.2.6 Advantages of Visual Studio

ASP.Net/C# can be programmed in a number of Integrated Development Environments (IDEs) or written using a simple text editor. Visual Studio .Net 2003 was chosen due to the benefits shown in Table 3.3

Feature	Benefit
Documentation	MSDN has a wealth of articles and examples
WYSIWYG web page designer	Allows easy creation of user friendly web pages
Pretty printer	Makes code easier to view

Table 3.3: Benefits of Visual Studio (Microsoft, 2005)

3.2.7 Other project tools

During the project a number of other tools will also be used to complete certain tasks, these are briefly described in Table 3.4.

Tool	Description
ADS MMC snap-in	Used to control the ADS server and view outcomes of the websites task submissions
ADS Sequence Editor	Used to create XML task files that instruct ADS on actions or steps to take
SQL Server	Used to hold the ADS and website database
Rational Rose	Used to create database diagrams
Office tools	Used to create the report

Table 3.4: Other project tools

3.3 Risk assessment summery

The risk assessment identified a number of potential problems the system could have encountered. All of the risks identified were assessed and solutions or contingencies produced. A network designs for the final system as also produced to reduce potential security problems even further. The full risk assessment can be seen in Appendix 3.4.

Chapter 4
Specification and design

4.1 Introduction

This chapter covers the final specification and the design of the website. It also covers the justifications and tradeoffs for specification and design decisions.

4.2 Specification

A specification helps to remove ambiguity about what the system will do and helps define the users 'true' requirements. The specification focuses on what the system will do, rather than how it will do it which is cover later in the design section. (Dawson, 2004)

4.2.1 Functional specification

Table 4.1 shows the functional specification of the website and the justification for each of the websites functions.

The website will	Justification
Allow the management of user accounts	To help with the maintenance of the website and allow user accounts to be added, edited and removed. Also, to aid with the website security.
Allow the management of ADS tasks	To allow user accounts to easily add, edit and remove ADS tasks from the website
Allow the management of computers	To allow users to include or exclude certain computers on the website. I.e. production computers may not want to be accessible from the website
Display new configurations entered in to the website separately	To allow technicians to easily see when a customer has made a request
Show a summary of running ADS tasks and ADS task errors	To provide users with some feedback about the state of their ADS tasks
Not allow 'bad' data to be saved to the database	If bad data cannot be saved to the database the website will have greater stability and will encounter less errors
Not to allow unauthorized viewing of pages	To provide extra security
Require users to login to the website	A user requirement for both security and for statistics
Have different security privileges	A user requirement for security
Allow the running of ADS tasks	A user requirement
Allow the queuing of multiple ADS tasks	A user requirement
Allow the design of full, multi computer setups	A user requirement

Continued over page…

Allow the running of multiple, sequential ADS tasks	A user requirement
Allow the saving and loading of previously run sets of ADS tasks	A user requirement
Show the statistics of computer, user and ADS task use	A user requirement
Allow customers to enter configuration change requests into the system	A secondary user requirement

Table 4.1: Functional specification

From the specification in Table 4.1, it can be seen that all of the users' primary requirements as discovered in Chapter 2 are being included in the website. Only one of the users' secondary requirements is included. This was to ensure the users' primary requirements were fully implemented and tested. Including all of the secondary requirements would have required a long time to implement; this would have impacted on the quality of the implementation of the user's primary requirements.

In addition to the specific user's requirements, functionality such as adding and removing user accounts has also been included. Although this was not specifically asked for by the users, it is required to fulfil the users' requirements.

4.2.2 Non-functional specification

Table 4.2 shows the non-functional specification of the website. This covers qualitative aspects of the website. These are not fixed features or capabilities, they are more of a general level of quality that the website tries meet.

The website will	**Justification**
Have 100% of errors with friendly error messages	Gives the user more confidence that the website functions correctly
Have error messages that are understood by most computer users	Helps users to solve their own problems without having to ask for help
Be robust to unexpected data	To stop unexpected errors occurring on the website
Be user friendly	Ensures users will be happy using the website
Be functional	Computing professionals prefer 'surface' functionality rather than 'hidden' functionality
Not submit errors to the ADS system	Ensures that computers will not be accidentally reformatted or altered in any adverse way
Follow HCI principles	Helps with the usability of the website
Be maintainable	Ensures the website will not become out-of-date and unusable

Table 4.2: Non-functional specification

4.3 Website design

To ensure the website is as easy to use as possible for the users, it was designed using Human Computer Interaction (HCI) principles and with usability in mind.

"If the interface is poorly designed, it can severely restrict the user's ability to use the system"
(Ravden and Johnson, 1989)

4.3.1 HCI principles

The main areas of HCI that were looked at in the design of the website were Semiotics and Defensive design. These areas were chosen as they were identified as important aspect of design for the website. If there were more time available other aspects of HCI could also have been looked at in more detail.

Semiotics is a very good way of improving design of a user interface (UI) as it associates things the user is already familiar with, to aspects of the UI.

"Semiotics is concerned with everything that can be taken as a sign"
(Eco, 1976) cited from (Chandler, 2004)

For example, the messages in Table 4.3 do not only tell the user information with written text, they also give the user information by their colour and the picture next to them.

Messages
Error: You did not type an input
Please type you username
The data was saved to the database

Table 4.3: Semiotics in use

These types of signs were used on the website to help improve feedback to the user.

Defensive design is designing the UI to help reduce user errors, correct user errors and recover from user errors (Garret, 2002). Figure 4.1 shows how defensive design reduces the number of user errors.

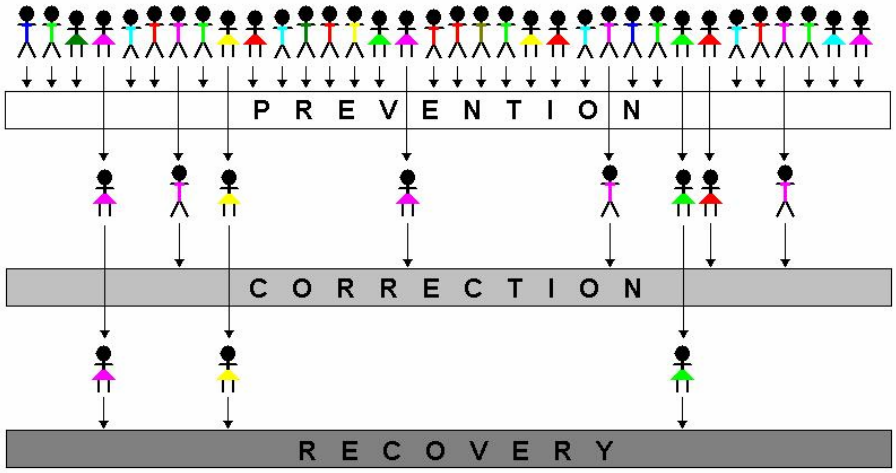


Figure 4.1: Defensive design (Garret, 2002)

Table 4.4 shows how the website UI addresses each level of defensive design.

Level	**Resolution**
Prevention	• Each data field has its name clearly indicated • Data field names are self describing • Each data field is a fixed selection choice where possible • Data fields dynamically update other options on selection • Page submission buttons grouped
Correction	• Dynamically checks data inputs before page submission • All data types are checked before the page submission is successfully accepted • All errors display a relevant error message
Recovery	• All page code is placed in try and catch code blocks • Page data is remembered and redisplayed

Table 4.4: Websites defensive design methods

Defensive design was not only used in the design of the websites UI, it was also used to secure access to the websites pages. Table 4.5 shows how each level of defensive design relates to each level of protection on the web pages.
In addition to the specific HCI elements used in the websites UI design, general HCI principles from Nielsen were followed. These ensured the site did not have any major design problems.

Level	**Protection**
Prevention	The user is redirected to the login page if they are not logged in
Correction	The user is redirected from the page if they are logged in but do not have permission to view the page they entered in as the URL
Recovery	The pages controls are disabled and an error message displayed if the user does not have permission to use them

Table 4.5: Web pages security methods

4.3.2 Design choice and justification

Throughout the design of the pages Microsoft's website was used as a reference. This made the ADS website look and feel more like an official Microsoft website. This is not only a benefit to the ILS team, as the site will look more professional, it should benefit anyone using the site as the design should be familiar to them, reducing the need for user learning. A screenshot of the 'view active configurations' page can been seen in Appendix 4.9 with the following design features highlighted.

Site layout
The layout of the website follows a design covered on Microsoft's bCentral. This design is not only a design used by Microsoft's website; it is a standard design used on lots of popular websites and follows many of Nielsen's Laws of Web User Experience.

This was chosen as any user should be familiar with the website design of a navigation bar on the left hand side and the main content to the right of it.

"Consistency is one of the most powerful usability principles: when things always behave the same, users don't have to worry about what will happen. Instead, they *know* what will happen based on earlier experience. Every time you release an apple over Sir Isaac Newton, it will drop on his head. That's *good*."
(Nielsen, 2004)

Colours
The main colours that are used on the website are shown in Table 4.6.

Colour	HEX	Where it is used
	#f1f1f1	Left sidebar
	#086dce	Panel headings and page title
	#cccccc	Table headers
	#e9e9e9	Alternative table items
	#ffffff	Standard background
	#000000	Text colour
	#ff0000	Error messages

Table 4.6: Colours used on the website

The colours in Table 4.6 were chosen as they are standard colours used by Microsoft. All of the colours were taken from the Microsoft website, which can be seen in Figure 4.2 and an additional page in Appendix 4.8.

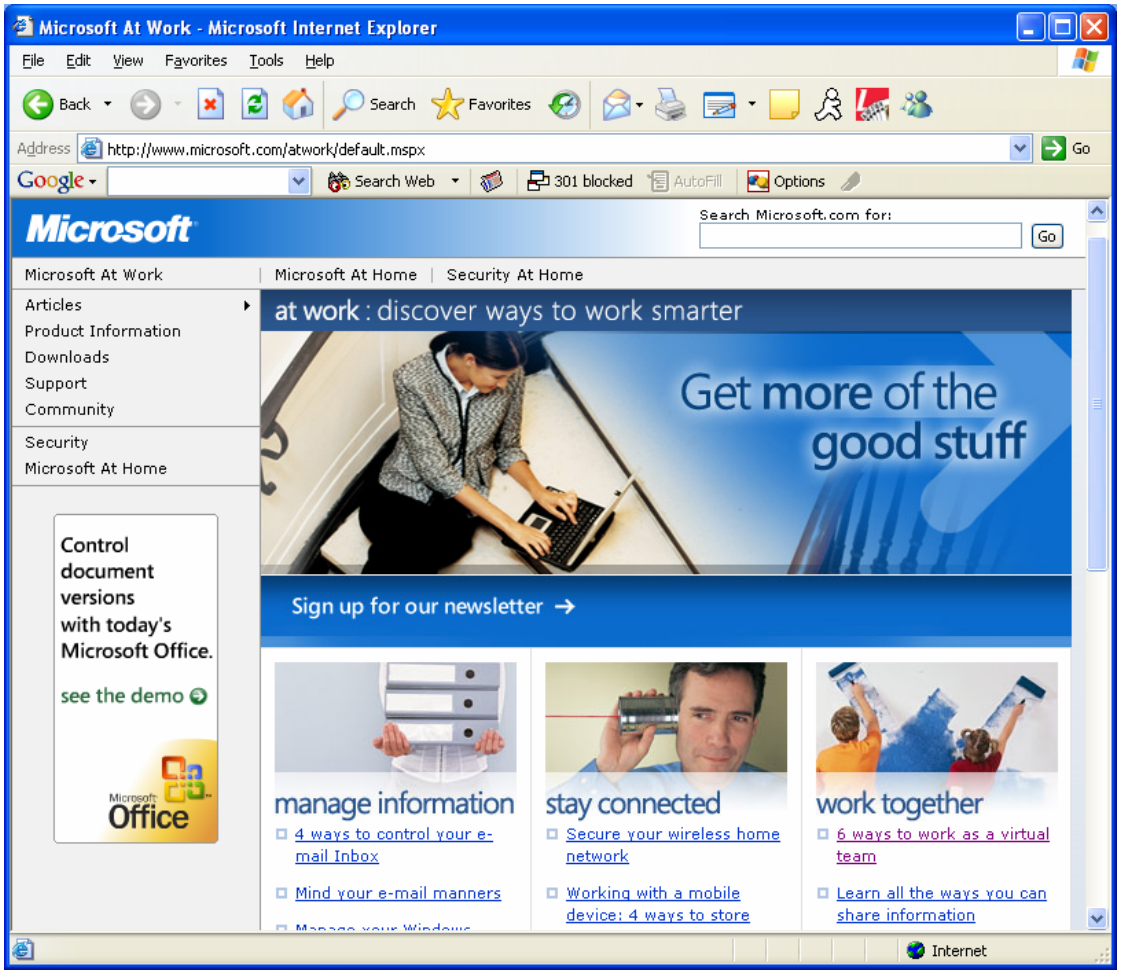


Figure 4.2: Screenshot of Microsoft's website

Hyperlinks
The links in the left navigation bar stay black when clicked, all other links on the website change colour when clicked. Nielsen says that hyperlinks should change colour when they are clicked. The links in the left navigation bar remain black however as they represent menu options and not standard page links. Allowing these links to remain black differentiates them from standard links to the user.

Menu bullet points
To further differentiate the left navigation menu from other links on the website they also have square bullet points next to them. These bullet points can be seen in Figure 4.2 in use on Microsoft's website.

Reusing of pages
The website reuses pages as much as possible, for example the configuration page is used to create new, edit existing and the view existing configurations. This was done to reduce the amount of learning that is required by the users. Learnability is one of the aspects of Usability as defined by the International Organization for Standardization (ISO) (Jordan, 1998). Since the website could be used by external customers from the ILS labs, increasing learnability will enable those users to complete tasks with less training. This can save both time and money.

4.4 Data modelling

4.4.1 Current database

ADS has a database that contains information about the computers in the data centre, consequently this information does not need to be stored in the website's database. To ensure the integrity of the ADS database, if there were an error with the website, a separate database has been created to hold any additional information the website needs. To further protect the data in the ADS database, the website only reads data from the ADS database, and uses WMI to write to the database. Although these steps add complexity, the extra safety they provide to the data out weighed the extra work required to implement them.

4.4.2 Identify entities and attributes

From studying ADS, it is easy to identify 3 main entities that work together to complete the process of installing software on a computer, shown in Table 4.7.

Entity	Description
The user	Physically starts the process
The task	The logic used to make the computer complete the task chosen by the user
The computer	The physical object the will be effected by the running of the task

Table 4.7: Identified database entities

As the website will provide more power and greater flexibility with 'the task' part of the process than ADS currently has, it will be extended as shown in Table 4.8. Figure 4.3 shows this extension in diagram form.

Entity	Description
The job	A list of tasks to be run on a list of computers
The configuration	A list of job to be run

Table 4.8: Extended entities from current ADS

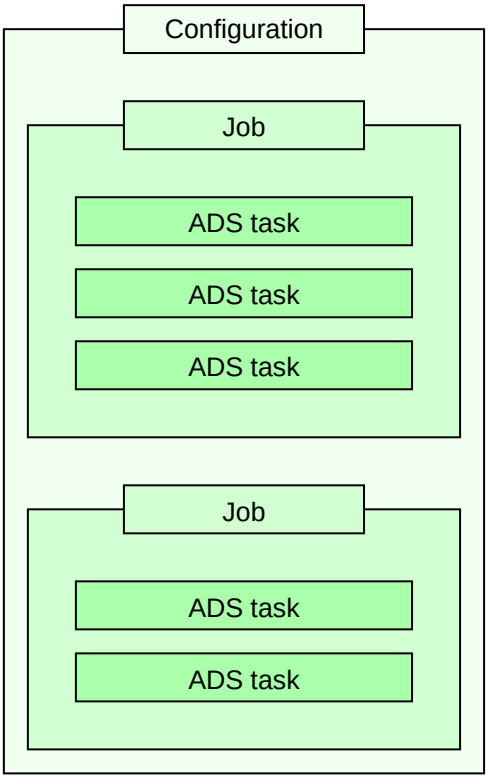


Figure 4.3: New task hierarchy using extended entities

For each of the five entities that have been identified in the process, a number of attributes that describe each of the entities can be produced.

The user entity (Appendix 4.1) – consists of user logon information and security privileges. There are a number of security privileges that the user can have, this is to give the maximum amount of granularity to the website security.

The task entity (Appendix 4.2) – provides a description of what a task does, the path to the XML file that instructs ADS on the actions it should take, information on which OSs the task will run on and counters to show how many times that task has been used. A Bit is used to identify if a task installs an OS, and what OS it is, as the user will only be allowed to choose one OS per job, due to multi-booting OSs not being supported.

The job entity (Appendix 4.3) – contains information on the job's creation, an ordered list of tasks included in the job and a Bit to indicate if the job is still active.

The username and date of creation of the job are stored to enable statistics to be produced about the activity of each user. In addition to this, future developments were taken into consideration and the possibility of users reusing other users' jobs in their own configuration, so it would be useful to know who created each job.

If a job is active, the computers used as part of that job are no longer listed on the new configuration page (as indicated by the IsActive Bit). This prevents users from accidentally reformatting computers that are still in use by other users.

This introduces a problem with users wishing to plan out a configuration in advance, as they will not be able to select computers that are in use now, but will not be in use when they actually want to apply the configuration. This is a difficult problem to overcome, as computers are not in use for a fixed period of time the website is unable to predict when a certain computer will no longer be needed by a user. As the data stored on the computers is valuable, the safest option was chosen of not letting users choose a computer unless it is not currently in use. This is to help prevent the accidental reformatting of computers.

The job entity will also have a description. This is not currently being used by the website but is included for future developments.

The configuration entity (Appendix 4.4) – contains information on the configuration's creation, a description, an ordered list of jobs in the configuration and an indicator of whether the configuration has ever been applied.

The indicator of whether the configuration has been applied or not will enable the website to list configurations that may be requests from a customer separately. As the username of the creator of the configuration is stored, a technician will be able to view all of the unapplied configurations and see which ones have been submitted by customers. This process could be further refined by indicating which user accounts are customers and only displaying those configurations. This was chosen not to be implemented as customers were identified as being the tertiary users of the website, in Chapter 2, so other features of the website took precedence.

The configuration does not require an indicator of whether it is active or not, as the jobs inside the configuration are active or inactivate the configuration inherits their status.

The computer entity (Appendix 4.5) – contains a foreign key to a the computer on the website with a computer in the ADS database, a foreign key to show what task the computer currently belongs to and counters to show how many times the computer has been used.

4.5 Entity relationship identification

As discussed in the previous section, there are five entities that will interact during the use of the website. In natural language, the user creates a configuration that contains jobs, the jobs contain tasks and the tasks will be run on a computer.

Table 4.9 describes the terminology that will be used to describe the relationships between the different entities.

Term	Description
0..1	Zero to one relationship
1..1	One to one relationship
0..n	Zero to many relationship
1..n	One to many relationship

Table 4.9: Description of relationship terms

In the database, the USER table will have a relationship with both the JOB table and the CONFIGURATION table. Both of the relationships for the user will be 1..1 to 0..n, as a user may or may not have created a number of jobs or configurations, but any job or configuration that was created was only created by one user.

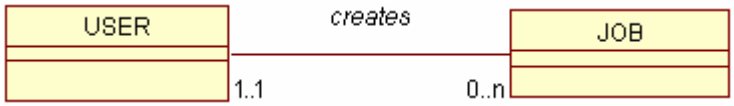


Figure 4.4: USER and JOB relationship

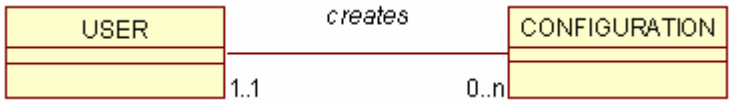


Figure 4.5: USER and CONFIGURATION relationship

In addition to both being related to the user the JOB and CONFIGURATION tables are also both related to each other, as a configuration is made up of a number of jobs. This will give the relationship 1..n to 1..n as many configurations could contain a particular job and many jobs may be in each configuration. Jobs and tasks are linked in a similar way, although tasks can exist without being included in a job.

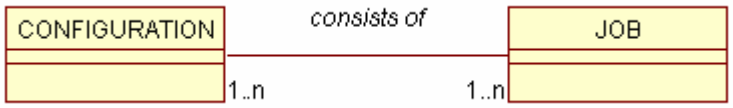


Figure 4.6: CONFIGURATION and JOB relationship

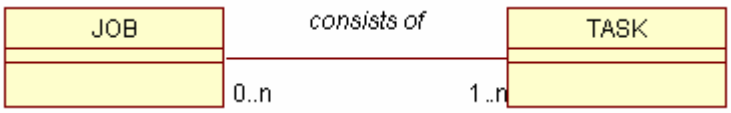


Figure 4.7: JOB and TASK relationship

In the ADS database the TASK table has a relationship with the COMPUTER table, as a singular task can be run on 1..n computers. Relating JOB, instead of TASK, to COMPUTER enables a number of TASK to be run on 1..n computers.

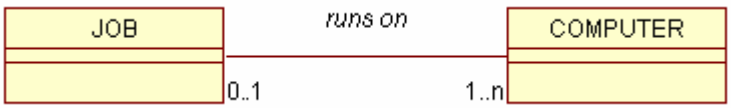


Figure 4.8: JOB and COMPUTER relationship

The full entity relationship diagram is shown below in Figure 4.9.

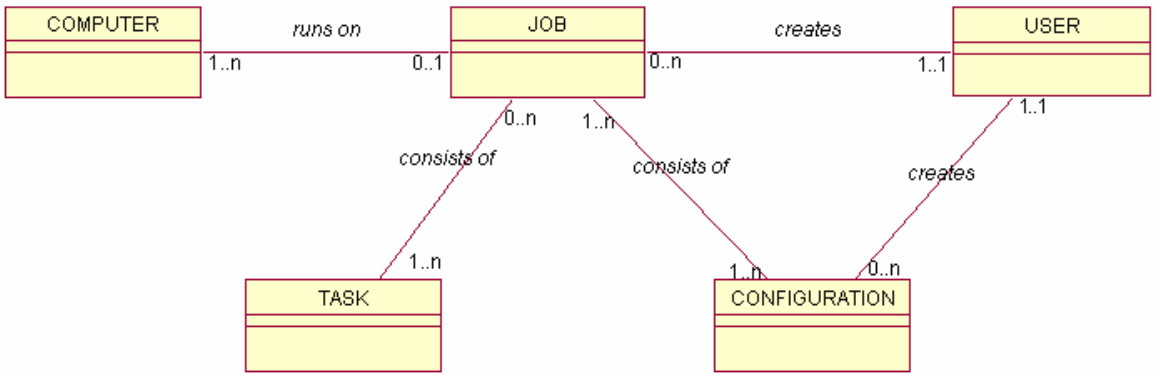


Figure 4.9: Complete entity relationship diagram

4.6 Normalization

As show in Figure 4.9, there are two many-to-many relationships present in the database design, these are JOB to CONFIGURATION and JOB to TASK. These relationships mean the design does not conform to the first normal form of database design.

"To be in first normal form a table cannot have more than one entry in any field" (Dawson, 2001:88)

To resolve this, a relationship table can be placed between each of these relationships.

To resolve the problem between JOB and TASK a new entity called JOBTASK was created. The relationship between TASK and JOBTASK is 1..1 to 0..n, as a TASK may or may not be used in a JOBTASK but for JOBTASK to exist it must contain one task. The relationship between JOB and JOBTASK is 1..1 to 1..n, as a JOB must contain at least one JOBTASK to exist and a JOBTASK can only belong to one JOB.

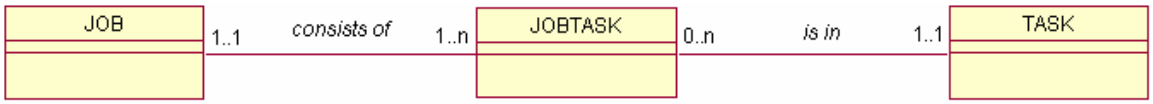


Figure 4.10: JOBTASK discovered entity

The solution to the CONFIGURATION and TASK relationship is similar, although if a JOB exists it must belong to a configuration so the relationship between JOB and CONFIGURATIONJOB is 1..1 to 1..n.

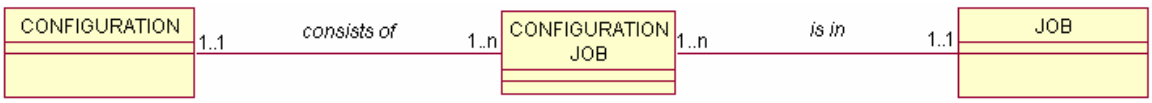


Figure 4.11: CONFIGURATIONJOB discovered entity

With all of the many-to-many relationships resolved a final entity relationship diagram was produced for the system, as shown in Figure 4.12.

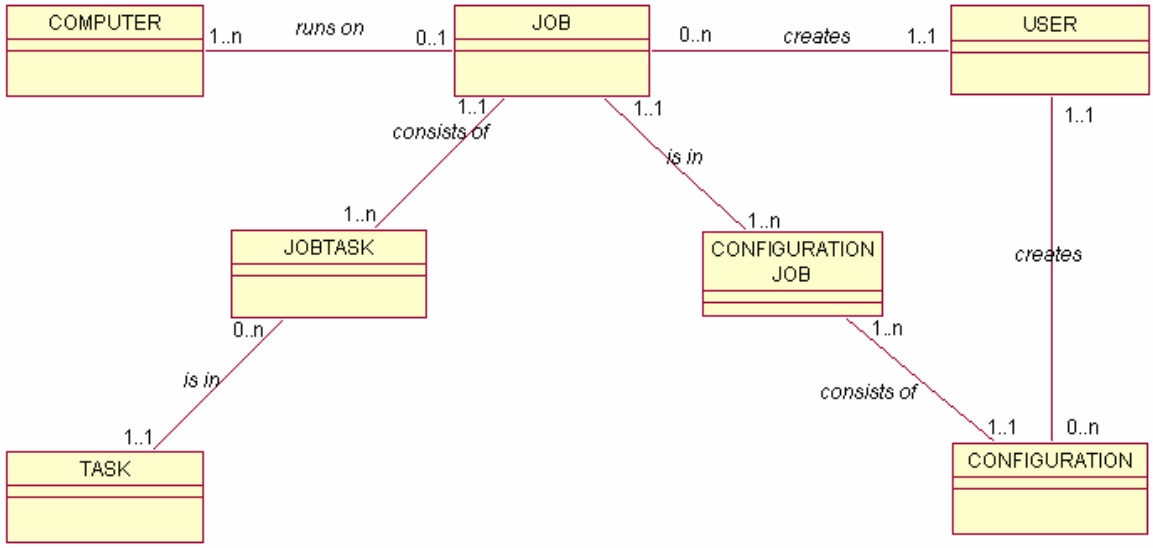


Figure 4.12: Final entity relationship diagram

The database conforms to the 1NF, 2NF, 3NF and BCNF of database design. It was decided not to make the database conform to 4NF and 5NF as these an advanced form of normalization and the website is not required for high performance operation.

4.7 Data Dictionary

With all the tables, attributes and relationships identified it is possible to create the data dictionaries that will be used in the database.

The USER, TASK and COMPUTER tables are as described in the original entity identification. These are show in Table 4.10, 4.11 and 4.12 respectively.

USER		
Attribute name	Data Type	Description
UserID	Integer	Unique auto-increment Primary Key
Username	Varchar(20)	Unique username
Password	Varchar (20)	Users password
CanView	Bit	Indicates if the user can view configurations
CanEdit	Bit	Indicates if the user can edit configurations
CanApply	Bit	Indicates if the user can apply configurations
CanActivate	Bit	Indicates if the user can activate configurations
CanDeactivate	Bit	Indicates if the user can deactivate configurations
CanSave	Bit	Indicates if the user can save configurations
IsAdmin	Bit	Indicates if the user is an Administrator
Active	Bit	Indicates if the user account is still active

Table 4.10: Final USER table

TASK		
Attribute name	Data Type	Description
TaskID	Integer	Unique auto-increment Primary Key
FullDescription	Varchar(500)	Long description of what the task does
ShortDescription	Varchar(30)	Short description on what the task does
XMLPath	Varchar(200)	File path to the XML file the task represents
WillRunOn2k	Bit	Indicates if the task will run on Windows 2000
WillRunOnXP	Bit	Indicates if the task will run on Windows XP
WillRunOn03	Bit	Indicates if the task will run on Windows 2003
WillRunOnLH	Bit	Indicates if the task will run on Windows Longhorn
IsXP	Bit	Indicates if the task installs Windows XP
Is2k	Bit	Indicates if the task installs Windows 2000
Is03	Bit	Indicates if the task installs Windows 2003
IsLH	Bit	Indicates if the task installs Windows Longhorn
CurrentCounter	Integer	Number of times the task has been run since the counter was last cleared
Counter	Integer	Total number of times that task has been run

Table 4.11: Final TASK table

COMPUTER		
Attribute name	Data Type	Description
ComputerID	Integer	Unique auto-increment Primary Key
JobID	Integer	Foreign Key indicating which job is using the computer JOB:JobID
ADSComputerID	Integer	Foreign Key linking the ADS database to the website database DEVICES:ID
CurrentCounter	Integer	Number of times the computer has been used since the counter was last cleared
Counter	Integer	Total number of times the computer has been used

Table 4.12: Final COMPUTER table

The computer table is the link between the ADS database and the website database. The link between the ADS database and the website database can be seen in Figure 4.13.

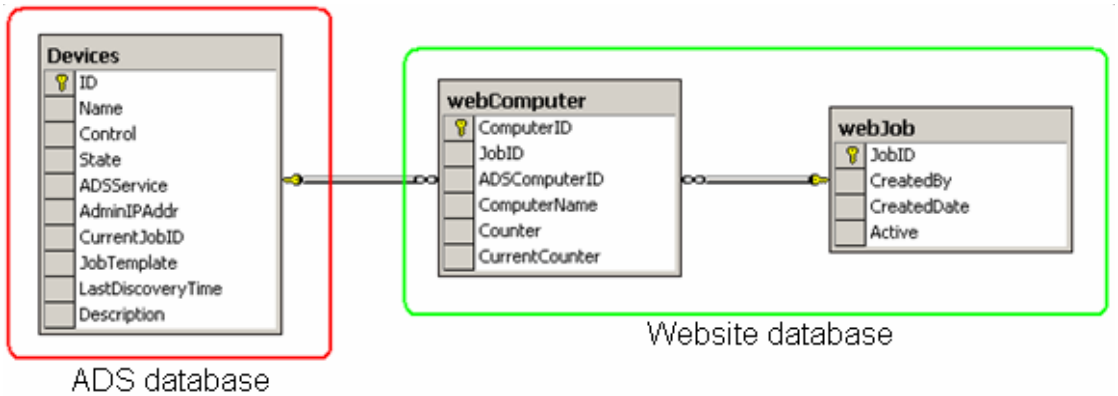


Figure 4.13: ADS and website database link

Pictures of the full website database with data tables and the full ADS database linked with the website data base can be seen in Appendix 4.6 and Appendix 4.7 respectively.

The JOB table no longer contains an ordered list of tasks as they are linked via the JOBTASK table and the CONFIGURATION table no longer contains a list of jobs as they are linked via the CONFIGURATIONJOB table. The JOB table can be seen in Table 4.13 and the CONFIGURATION table in Table 4.14.

JOB		
Attribute name	Data Type	Description
JobID	Integer	Unique auto-increment Primary Key
CreatedBy	Integer	Foreign Key USER:UserID
CreatedDate	DateTime	The date and time the job was created
Active	Bit	Indicates if the job is still active

Table 4.13: Final JOB table

CONFIGURATION		
Attribute name	Data Type	Description
ConfigID	Integer	Unique auto-increment Primary Key
Description	Varchar(30)	Description of what the configuration does
CreatedBy	Integer	Foreign Key USER:UserID
CreatedDate	DateTime	The date and time the job was created
IsNew	Bit	Indicates if the configuration has ever been applied

Table 4.14: Final CONFIGURATION table

The JOBTASK table and the CONFIGURATIONJOB table were both identified during the normalization of the database. Each of these tables contains it own attribute, Position, to identify in what order each entry should appear. The JOBTASK and the CONFIGURATIONJOB tables can be seen in Tables 4.15 and 4.16 respectively.

JOBTASK		
Attribute name	Data Type	Description
JobID	Integer	Foreign Primary Key
TaskID	Integer	Foreign Primary Key
Position	Integer	Primary Key

Table 4.15: Final JOBTASK table

CONFIGURATIONJOB		
Attribute name	Data Type	Description
ConfigID	Integer	Foreign Primary Key
JobID	Integer	Foreign Primary Key
Position	Integer	Primary Key

Table 4.16: Final CONFIGURATIONJOB table

Chapter 5
Implementation

5.1 Introduction

The following chapter covers the implementation of the website. It includes explanations of problems overcome during the creation of the website and a description of each section of the website.

5.2 Website map

The website consists of 12 webpages. Each page can function independently, provide user feedback and process its own submission. This was done intentionally to minimise the number of web pages whilst maintaining the functionality of a larger website. This keeps the code for pages together, rather than splitting it across numerous pages, allowing easier editing of sections of the website. Figure 5.1 shows a map of the website.

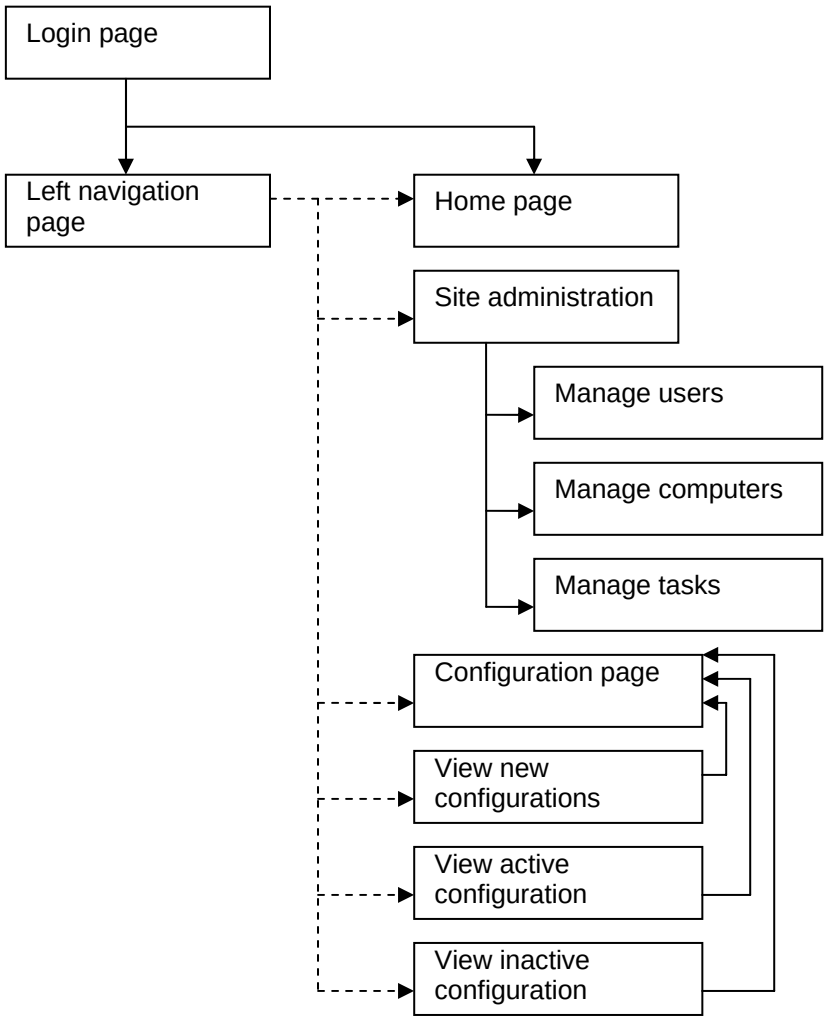


Figure 5.1: Website map

5.3 Database creation

All the tables were created with the word ‘web’ in front of them to distinguish them from tables in the ADS database. They were created using the SQL enterprise manger to create a SQL server database. Once the database tables, covered in Chapter 4, were created and the primary keys selected the relationships between the tables were created. These were created using the relationships tab in the properties of each of the tables. Finally, the ASP.NET user account on the web server was given permission to access the database. This allowed the website to use integrated security to access the database, rather than requiring a username and password. Extract 5.1 shows the code to access the database.

```
SqlConnection conn = new SqlConnection(@"Data Source=(local);
Initial Catalog=adsdb;Integrated Security=true");
```

Extract 5.1: Code to create a connection to the website database

Integrated security was chosen as it allows the password of the user account to be changed without the password also having to be changed in the source code of the webpages.

5.4 Login page

The login page checks the username and password entered by the user against entries in the database. As with all the pages on the website, to ensure data being submitted to the database are valid they are changed to the correct format before being sent, as shown in Extract 5.2.

```
// Create SQL command to check password
SqlCommand cmd = new SqlCommand("SELECT * FROM webUser
WHERE Username=@Username AND Password=@Password",conn);

// Create cmd parameters for Username and Password
cmd.Parameters.Add("@Username",SqlDbType.VarChar);
cmd.Parameters.Add("@Password",SqlDbType.VarChar);

// Set the parameter to the users input
cmd.Parameters["@Username"].Value=txtUsername.Text;
cmd.Parameters["@Password"].Value=txtPassword.Text;
```

Extract 5.2: Data being formatted as a SQL data type

Correctly formatting the data allows the webpage to handle errors before the data are sent to the database. This does not only ensure invalid data are not submitted to the database, it also improves efficiency as the webpage does not have to wait for a reply from the database before it can inform the user there is an error. There is also an adverse effect that five lines of code are required instead of one. It was decided that the inclusion of more lines of code was an acceptable trade off for data validity.

In addition to logging in the user, the login page also put the user's information in a session variable that it is available to other pages on the website, therefore it does not have to be read from the database every time it is needed. The prototype page is shown in Appendix 5.1 and the final page in Appendix 5.2.

5.5 Left Navigation page

The left navigation page provides hyperlinks to different pages on the website. It uses the user information to decide which links are clickable by the user, i.e. if the user is not an administrator the hyperlink for the administration menu is disabled. The original design presented the user with buttons, these were changed to hyperlinks for aesthetic and usability reasons. The prototype and final menu can be seen on the left side of Appendix 5.4 and Appendix 5.5 respectively.

5.6 Home page

This page gives the user a brief summary of the activity of the Automated Deployment Services (ADS) server if the user has the permissions to see the information. As the login page puts the user's information in a session variable, any of the webpages can read this information back with the code in Extract 5.3.

```
private DataGrid GetUserInfo()
{
   // Create the user information datagrid
   DataGrid dtgUserInfo= new DataGrid();
   string teststring;

   // Try to get user information, if not present redirect to login page
   try
   {
      dtgUserInfo = (DataGrid)Session["UserInfo"];
      teststring=dtgUserInfo.Items[0].Cells[0].Text;
      return dtgUserInfo;
   }
   catch
   {
      Response.Redirect("login.aspx");
      return null;
   }
}
```

Extract 5.3: Method to retrieve user information

Not only does Extract 5.3 retrieve the user's information, it also redirects the user to the login page if this information cannot be retrieved, i.e. the user has not logged in. A session variable was chosen over a cookie to pass the information as the information in a session variable will be lost once the user closes the browser or after a timeout period, so the user does not have to worry about the security risks of leaving information in a cookie on the computer they are using to access the website.

Once the page has the user's information, it can decide if the user has the correct permissions to view a summery of the ADS server's activities, i.e. the view permission. If the user does have view permissions the page calls three separate methods to display the new configurations, running configurations and error messages. Each of these methods is similar; the method to read and display the running configurations is show in Appendix 5.3.

The home page differs slightly from the original prototype. It was decide that the user would not be shown a full list of new configurations as this list became very large, to avoid long scrolling pages they are informed there are new configurations and given a link to view them. The user cannot click on the running configurations or the errors to get more information as shown in the prototype due their being limited documentation, so the time required to implement this would have outweighed the benefits it provided. The prototype design is shown in Appendix 5.4 and the final design in Appendix 5.5.

5.7 Configuration page

The configuration page is by far the most complex page of the website. It allows the creation, loading, saving, viewing, editing and application of configurations. There are over 1,500 Lines Of Code (LOC) for manipulation of data between the website, database and the ADS server.

5.7.1 Loading of a configuration

When a user wants to view, edit or apply an existing configuration, the ConfigID of that configuration is passed to the configuration page via a session variable, in the same way that the user's information is passed. Table 5.1 shows the process the page follows when it receives a ConfigID to load. The LoadComputer method is shown in Appendix 5.6.

To reduce the number of times the website has to access the database, to improve performance, the SQL commands join tables where possible to retrieve all the data required in one trip. Extract 5.4 shows an example of a SQL statement joining tables when the TaskIDs and their position numbers are read for a configuration.

```
cmd = new SqlCommand("
SELECT webJobTask.TaskId, webJobTask.PositionNo
FROM webJobTask INNER JOIN webConfigJob
ON webJobTask.JobId=webConfigJob.JobID
WHERE webConfigJob.ConfigID=@ConfigID
ORDER BY webJobTask.PositionNo",conn);
```

Extract 5.4: SQL statement joining database tables

No	Method	Description
1	LoadOSTasks() 44 LOC	• Select all tasks that install OSs • Loop through each OS task box and bind the tasks to the box • Loop through each OS task box and select the OS that was selected when the configuration was saved
2	LoadConfig() 134 LOC	• Get the configurations description • Get all the jobs in the configuration • Loop through each job and call LoadOtherTasks(Job Position) • Loop through each job and update the other task boxes to select the task that was selected when the configuration was saved
3	LoadOtherTasks(int) 132 LOC	FOR EACH JOB • Select all the tasks that will run on the OS selected, or all tasks if no OS is selected • Loop through each task box and bind it to the tasks
4	LoadComputers() 116 LOC	• Select all free computer and computers in the configuration • Loop through each of the computer list boxes, bind the computers and select the ones that are in use by the configuration

Table 5.1: Steps taken to load a configuration

5.7.2 Saving of a Configuration

When a user wants to save the configuration it is written to the database. As with all the webpages the data is converted into the correct SQL data type before being submitted to the database. To further ensure the data saved to the database is correct, in addition to valid, the page runs a number of error checking methods. Although the page takes longer to submit and increases its size, it is worthwhile to ensure the information in the database is correct. Table 5.2 shows the process the page takes to save the configuration to the database.

No	Method	Description
1	btnSave_Click 28 LOC	• Check there is a short description • Call CheckIsIncludedWithNoTasks() • Call ComputersOnlySelectedOnce() • Call SaveConfigToDatabase()

2	CheckIsIncluded_
	WithNoTasks()
	106 LOC
		• Copy the Include Job check boxes
		• For each checked check box
		  • Copy the Jobs task boxes
		  • Check to see if at least one of them has a task selected
		• Return True if a Job is selected without any tasks selected and False if all Jobs checked have tasks selected

3	ComputersOnly_
	SelectedOnce()
	75 LOC
		• Copy the computer list boxes
		• Set OnlySelectedOnce=true
		• For each list box
		  • For each list box after the current list box
		  • Check each selected computer in the current list box to the selected computers in the list boxes after
		  • If the same computer is selected in both boxes display an error and set OnlySelectedOnce=false
		• Return OnlySelctedOnce

4	SaveConfigToDatabase()
	270 LOC
		• Insert the config information in to webConfig
		• Read back the new ConfigID
		• Loop through each job that is selected
		  • Copy the tasks selected in the current job
		  • If there are tasks selected Insert the job into webJob
		  • Read back the new JobID
		  • Insert a link to the config into webConfigJob
		  • If there is an OS task selected Insert a link into webJobTask
		  • Loop though the other tasks and Insert a link into webJobTask if they are selected
		• Set the JustSaved state variable to true

5	On page reload as JustSaved=True	• Load the configuration from the database

Table 5.2: Steps taken to save a configuration

As checking every computer recursively to see if it is selected twice could take a lot of time the ComputerOnlySelectedOnce method uses four nested loops with three additional nested if statements to only check computers that have been selected for efficiency. The ComputerOnlySelectedOnce method can be seen in Appendix 5.7.

5.7.3 Applying a configuration

Applying a configuration was the most challenging part of the project. This is where the tasks selected by the user are converted to XML files ADS can understand, and the configuration is submitted to ADS to be run.

As applying a configuration was such a complex process, it was split up into a number of smaller tasks of reading all the correct information from the database, creating XML files, joining XML files, creating ADS computer sets and running ADS jobs. Once all of the sections worked separately they were bought together to enable a configuration to be applied.

XML task files

The XML task files are sequences of steps that an ADS server will understand and can follow. These file were created using the ADS sequences editor, a sample file created to install .NET framework can be seen in Appendix 5.8. Each one of these XML files completes a number of steps to complete a single task, so to enable ADS to run a number of tasks sequentially these XML files must be merged.

XML wrapper file and XSLT document

To merge the XML tasks files together, a wrapper document is first created that lists all the XML task files to be joined, a sample wrapper document can be seen in Appendix 5.9.The wrapper file then has a XSLT document applied to it, this can be seen in Appendix 5.10. The XSLT document takes the file paths from the wrapper document and outputs another XML file that includes all the steps from all of the source files. Figure 5.2 shows a graphical representation of this process.

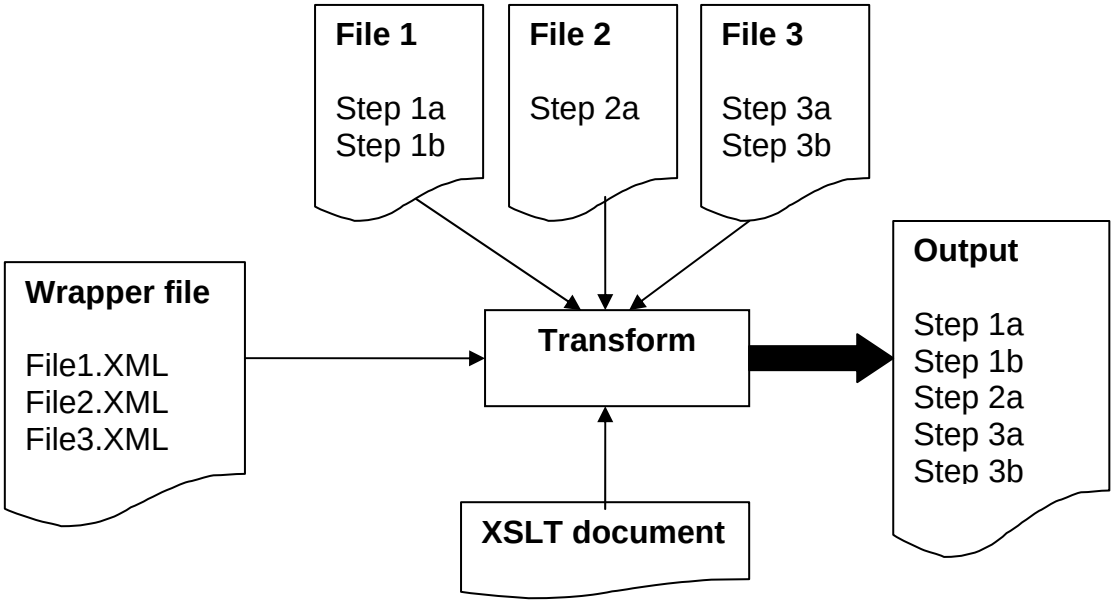


Figure 5.2: Joining of XML tasks

The full application process

In addition to merging XML files there are a number of other actions that take place before a configuration is applied. Table 5.3 shows the steps taken by the website when the Apply button is pressed.

No	Method	Description
1	CheckIsIncluded_ WithNoTasks	See Table 5.2
2	ComputersOnly_ SelectedOnce	See Table 5.2
3	ComputerIs_ Selected(int) 35 LOC	• Set FoundOne=False • Loop through the computer list box represented by the passed int • If a computer is selected set FoundOne=True • If FoundOne=False update the error message • Return FoundOne
5	SaveConfigTo_ Database()	See Table 5.2

4	ApplyConfig(int, int) 336 LOC	• Read the jobs in the config from webConfigJob
		• For each job read in all of the tasks from that job from webJobTask
		• For each job
		  • Create a XML file to represent the job
		  • For each task in the job
		  • Update the usage statistics
		  • Read the XML path for the task from webTask
		  • Write the XML path for the task to the jobs XML file
		  • Close the jobs XML file
		  • Transform the jobs XML file using the XSLT document to include the full XML document
		• For each job
		  • Create a new Set of computers in ADS using WMI
		  • Add all of the computers in the current job to the set
		  • Update the computer usage statistics
		• For each job
		  • Run the outputted XML file on the computer Set in ADS using WMI
		• Update the config in webConfig so that it is no longer marked as new

Table 5.3: Step taken to apply a configuration

Figure 5.3 shows a flow diagram of the process of applying a configuration.

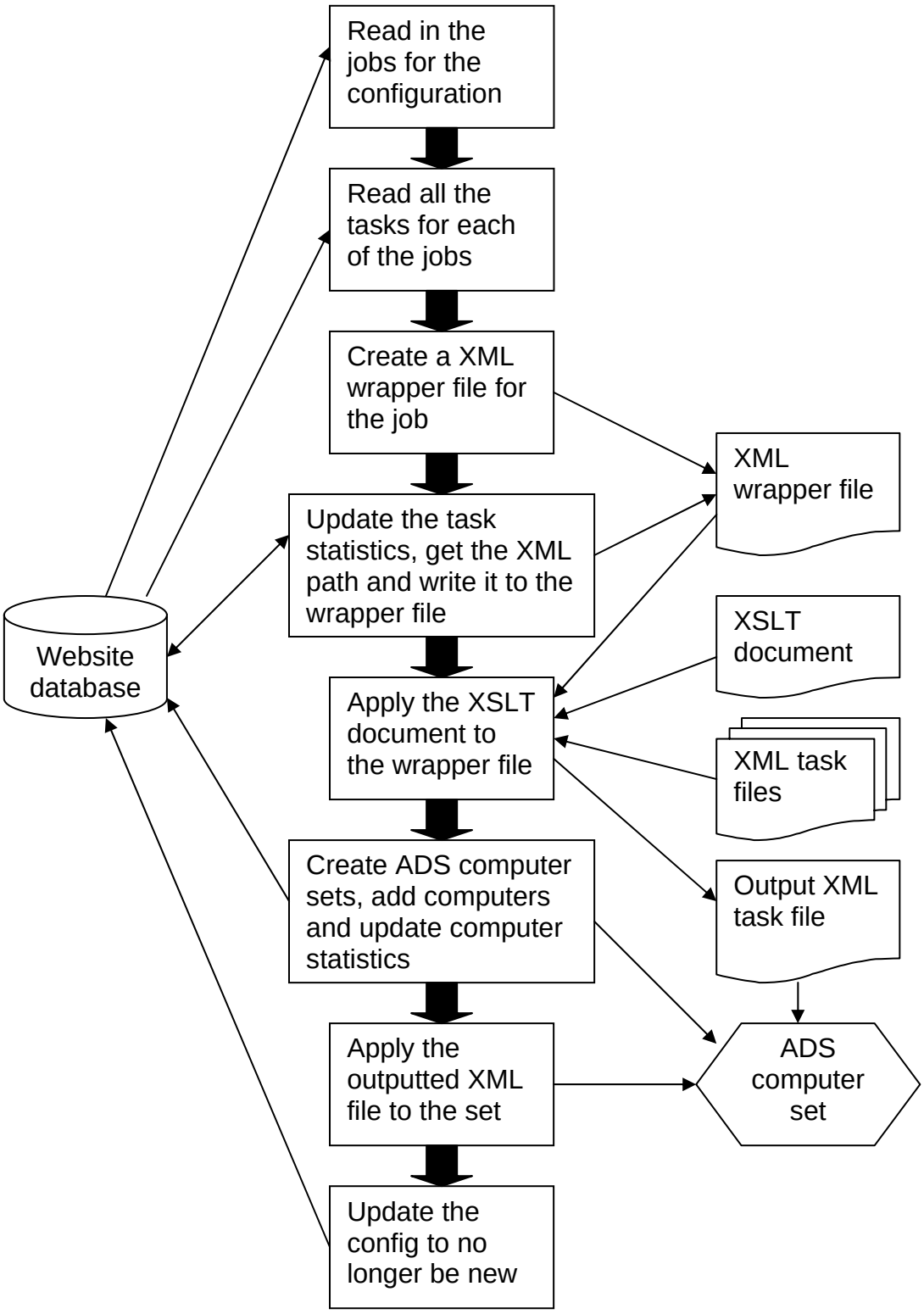

Read in the jobs for the configuration
Read all the tasks for each of the jobs
Create a XML wrapper file for the job
Update the task statistics, get the XML path and write it to the wrapper file
Apply the XSLT document to the wrapper file
Create ADS computer sets, add computers and update computer statistics
Apply the outputted XML file to the set
Update the config to no longer be new
Website database
XML wrapper file
XSLT document
XML task files
Output XML task file
ADS computer set

Figure 5.3: Flow diagram for applying a configuration

Appendix 5.11 shows the code that creates the XML wrapper file and merges the XML documents. Appendix 5.12 show the code that creates the ADS computer sets, adds the computers and updates the computer statistics. Appendix 5.13 shows the code to apply the XML configurations to the ADS computer sets created.

The ApplyConfig method takes two parameters, ApplyConfig(int RunFromOnwards, int RunOnly). The first parameter makes the method apply only jobs that have an equal or value higher than it, i.e. if the parameter equals 3 only jobs three and four are applied. The second parameter make the method only apply the job number of the parameter, i.e. if the parameter equals 2 only job two will be applied. This allows the user to be selective about which jobs to run.

The final page design was similar to the prototype design, these can be seen in Appendix 5.15 and Appendix 5.14 respectively. The main difference is that the final page cannot dynamically create tasks or jobs, it is fixed to five tasks per job and four jobs per configuration. This was due to difficulties in getting dynamically created controls to remember their values after a page submission. As there is no efficient way of doing this, it was decided that fixing the number of jobs would be an acceptable trade-off for the amount time that could then be saved and spent on other areas of the website.

5.8 View configuration pages

When a user wants to either view new, active or inactive configurations they are read from the database. There is a separate page to list configurations in each state. The pages are separate as users have different permissions, e.g. a user may be able to view new configurations but not view inactive configurations.

To ensure users can only perform actions they have permissions to perform the pages check the user's privileges. Extract 5.4 shows a cut down version of the code that performs the check.

```
//find out if the user has permissions to deactivate tasks
//Get the userinfo
DataGrid dtgUserInfo=GetUserInfo();

if(dtgUserInfo.Items[0].Cells[7].Text =="True")
{
   // Let the user perform the action
}
Else
{
   // ERROR: The user does not have the permissions to do this task
}
```

Extract 5.5: Code to check the user's privileges

Extract 5.5 uses the command if(dtgUserInfo.Items[0].Cells[7].Text =="True") to check if the user can deactivate configurations. The index used in the Cells array relates to the row number of an attribute in the webUsers table of the database. Table 5.4 shows the row number of each of a user's attributes.

Row Number	Attribute Name
0	UserID
1	Username
2	Password
3	CanView
4	CanEdit
5	CanApply
6	CanActivate
7	CanDeactivate
8	CanSave
9	IsAdmin
10	Active

Table 5.4: User attribute row numbers

The final view configurations pages differed from the prototype designs slightly; these can be seen in Appendix 5.17 and Appendix 5.16 respectively. The page no longer has a ‘view’ link as the configuration is automatically set to read only if the user does not have permission to edit it. Also, there is no longer a ‘Reapply’ link, as it was decided it was safer to force the user to view the configuration before they reapplied it, to make sure they did not reformat the wrong computers by mistake.

5.9 Administration page

The administration page simply displays three hyperlinks to the manage tasks, users and computer pages. A final screenshot of the administration page can be seen in Appendix 5.18.

5.10 Manage users, tasks and computers pages

The manage users, tasks and computer pages allow administrators of the website to manage and maintain it.

Manage users page
The manage users pages is similar to the user administration page on many websites. This page can add and edit user accounts. However, the page cannot delete user accounts as this would remove information about users who may have created configurations. Instead, the page allows administrators to disable user accounts.

Appendix 5.19 shows the manage users page allowing administrators to create user accounts and Appendix 5.20 show the page allowing administrators to edit user accounts. When the administrator switches between the create and edit mode the username input switches from a text input box to a dropdown selection box, allowing them to select the user they want to edit from a list, this is an aspect of defensive design and usability.

Manage tasks page
The manage tasks page allows administrators to create database entries that link a task on the website to a XML file on the hard disk. The administrator can also edit tasks in a similar way used on the manage users page. Appendix 5.21 shows the manage tasks page allowing administrators to create tasks and Appendix 5.22 shows the page allowing them to edit tasks.

Manage computers page
The manage computers page allows an administrator to create a link between a computer in the ADS database and the website. This is a simple task of selecting the computers they want to be visible on the website and clicking ‘Add’. If they want all computers to be listed on the website they can click ‘Add All’. To remove links from the website to the ADS database they can click ‘Remove’ or ‘Remove All’. The manage computers page is shown in Appendix 5.23.

5.11 Statistics page

The statistics page allows administrators to view the usage statistics for tasks, computers and users. It reads the values from the database and displays them to the user. The users can reset the statistic counters so they could for example see what task have been used each week. The final design for the statistics page is shown in Appendix 5.24.

5.12 Style sheet

To ensure consistency in the style of the website a Cascading Style Sheet (CSS) was used. This was only very simple and set the website font and table style. Further formatting could be added, if needed, that would automatically be applied to every page on the website.

Chapter 6
Testing and evaluation

6.1 Introduction

The following chapter covers the testing and evaluation of the website.

"Users have an infinite potential for making unexpected misinterpretations of interface elements and for performing their job in a different way than you imagine" (Nielsen, 1994).

The testing of the website was split into a number of categories to ensure each part of the website was tested thoroughly as a single error could mean vital business data would be lost.

6.2 Testing outline

6.2.1 Unit testing outline

Table 6.1 outlines the types of unit testing carried out on the website, these were to ensure each control and function of the website worked correctly when used.

Testing type	Description
Control validation testing	Every control on the website was tested to ensure it preformed the correct actions when it was used
Control verification testing	The code for each control was tested to ensure that it preformed the correct action in the correct way
Function validation testing	Every function on the website was tested to ensure it produced the correct result
Function verification testing	Each function on the website was tested to ensure it could handle errors correctly and was producing the correct output in the correct way

Table 6.1: Types of unit testing performed on the website

6.2.2 Integration testing outline

Table 6.2 outlines the types of tests that were used to assess how well the web pages integrated with each other.

Testing type	Description
Test cases	Common scenarios were run through to ensure the different parts of the website worked together
Security testing	Each page was tested to ensure it was secure from unauthorised access and use

Table 6.2: Types of integration testing performed on the website

6.2.3 Acceptance testing outline

Table 6.3 outlines the types of tests used to evaluate how well the website met the user's needs.

Testing type	Description
Usability testing	The site was tested by users to see if the site was easy to use
System testing	The site was tested against the users requirements to see if they were met
Functional testing	The site was tested against the system specification to see if it was fulfilled

Table 6.3: Types of acceptance testing performed on the website

6.3 Unit testing

Table 6.4 shows the web pages that passed all of the unit tests. These pages are able to handle unexpected errors and prevent bad data from being entered into the database. Error and status messages that are displayed by the pages are listed in Appendix 6.1 and Appendix 6.2 respectively.

Page name	Test results
Login page	Appendix 6.3
Home page	Appendix 6.4
View unapplied configurations page	Appendix 6.5
View active configurations page	Appendix 6.7
View inactive configurations page	Appendix 6.8
Statistics page	Appendix 6.9
Manage users page	Appendix 6.10
Manage computers page	Appendix 6.11
Left menu page	Appendix 6.13

Table 6.4: Web pages that passed all unit tests

Table 6.5 shows the web pages that failed at least one of the unit tests. These pages had at least one component that either did not function correctly or allowed errors to be entered into the database.

Page name	Test results
New configurations page	Appendix 6.6
Manage tasks page	Appendix 6.12

Table 6.5: Web pages that did not pass all unit tests

Although the new configurations page failed 18 tests, all of the failures were due to two over stringent error checking functions. For example, if the user wanted to apply Job 4 only, and there was an error in Job 1, the page would not let Job 4 be applied. This problem was due to the affected functions checking the configuration as a whole, instead of each job individually. This was fixed by changing the following two functions to accept a job number:

ComputersOnlySelectedOnce() > ComputersOnlySelectedOnce(int JobNumber)
CheckIsIncludedWithNoTasks() > CheckIsIncludedWithNoTasks(int JobNumber)

The manage tasks page failed one test, test number 299, it allowed an invalid path to be entered for the task XML document. This error was fixed by changing the textbox to an 'Open File' dialog, only allowing the user to select XML files.

6.4 Integration testing

6.4.1 Test cases

A number of test scenarios were run on the website to ensure the different parts of the website worked together. As expected, after the successful unit testing the website passed all of the test cases without any problems. An example test case can be seen in Appendix 6.14.

6.4.2 Security testing

Each of the pages was subject to a number of security checks that fell into the three levels covered in Chapter 4; these are shown in Table 6.6.

Level	Description
1	The user is redirected to the login page if they have not logged in
2	The user is redirected from the page if they do not have the permissions to view the page
3	The page controls are disabled if the user does not have the permissions to use them

Table 6.6: Levels of page security

Table 6.7 shows the results of the security tests on the pages. All of the pages reached the maximum security level of Level 1. The login page was not included, as all users need to be able to access this page.

	Home page	View unapplied configurations page	View active configurations page	View inactive configurations page	New configurations page	Statistics page	Manage users page	Manage computers page	Manage tasks page	Left menu page
Level 1										
Level 2										
Level 3										

Table 6.7: Security levels of the web pages

6.5 Acceptance testing

6.5.1 Usability testing

There was only one major usability issue with the website which was the terminology used, this confused users about how to run tasks on computers.

The users became confused as ‘jobs’ and ‘configurations’ are not part of a normal ADS system, and they tested the website without being told what jobs or configurations were. ADS only allows users to run tasks, so a user must learn that on the website a job is a number of tasks and a configuration is a number of jobs. This problem can be avoided in future by users being shown the User Manual before they use the website.

All of the other usability issues on the website were minor, a full list can be found in Appendix 6.14.

6.5.2 System testing

Table 6.8 shows the users’ original requirements and which requirements the website met.

Requirement	
Ability to run ADS tasks remotely	Fully met
Ability to queue ADS tasks	Fully met
Ability to design full, multiple computer setups	Met with constraints
Ability to reapply saved computer setups	Fully met
Ability to produce statistics on computer and software usage	Fully met
The system must have some form of security	Fully met

Table 6.8: How well the user requirements were met

All of the user requirements were met although the user is currently limited to four jobs in a single configuration. This is because there was no efficient way to dynamically create tasks and jobs. This can be changed in the code to allow more than four jobs per configuration, or could be solved by splitting large setups into a number of smaller configurations.

6.5.3 Functional testing

Table 6.9 shows the functional specification for the website and which parts of the specification are met.

The website will	
Allow the management of user accounts	Fully met
Allow the management of ADS tasks	Fully met
Allow the management of computers	Fully met
Allow the running of ADS tasks	Fully met
Allow the queuing of multiple ADS tasks	Fully met
Allow the designing of full, multi computer setups	Met with constraints
Display new configurations entered in to the website separately	Fully met
Allow the running of multiple, sequential ADS tasks	Fully met
Allow the saving and loading of previously run sets of ADS tasks	Fully met
Allow customers to enter configuration change requests into the website	Fully met
Show the statistics of computer, user and ADS task use	Fully met
Require users to login to the website	Fully met
Have different security privileges	Fully met
Show a summery of running ADS tasks and ADS task errors	Fully met
Not to allow unauthorized viewing of pages	Fully met
Not allow bad inputs to be saved to the database	Fully met

Table 6.9: How well the functional specification was met

The website fully met the functional specification but again was limited to four jobs per configuration.

Table 6.10 shows the non-functional specification for the website and which parts are met. As the non-functional specification is qualitative, whether the specification was met was decided by the users' feedback in relation to the size of the project. For example, the website followed the chosen HCI principles well, but there are thousands more that were not used as part of the website due to time constraints.

The website will	
Have 100% of errors with friendly error messages	Fully met
Have error messages that are understood by most computer users	Mostly met
Be robust to unexpected data	Fully met
Be user friendly	Mostly met
Be functional	Fully met
Not submit errors to the ADS system	Fully met
Follow HCI principles	Fully met
Be maintainable	Fully met

Table 6.10: How well the non-functional specification was met

The website fully met nearly all of the non-functional specification and mostly met the other parts. It was decided the website was not totally user friendly as users needed to be told a definition of a job and a configuration.

"Error messages should always be constructive and help users to overcome the problem instead of simply pointing out that there is trouble"
(Nielsen, 2000).

The users decided that the error messages were not as clear as they could have been as they did not provided enough explanation on how to fix the error, although they did provide an accurate description of what error occurred.

6.6 Evaluation and testing summery

The unit testing provided 100% coverage of the code for errors, and out of the 19 errors found the website only required three code changes to fix them all. The code should also be able to handle 100% of both expected and unexpected errors.

The integration testing passed all of the test cases and achieved the highest security level on every web page. This was helped by the successful unit tests and ensured the user's security requirements were met.

The user acceptance testing also went very well and the issues were easily solved. The website met all of the customer's requirements and the original specification. The only limitation of the website is that it imposes a limit of four jobs per configuration on the user. This was accepted by the user as the actual functionally behind the website is present and it is not just a dummy website.

Chapter 7
Conclusion and future developments

7.1 Introduction
The following chapter covers the conclusion of the project and the future improvements that could be made to the website.

7.2 Project summary
The project as a whole went very well and the solution created was suitable to be used by the Microsoft Infrastructure and Laboratory Support (ILS) labs. All of the users' primary requirements were met and ILS team were happy with the extra functionality the website provided. Although the website created was primarily designed for the ILS team, different organisations were taken in to account, which gives the website a greater portability across organisations. Greater portability also means the website will better cope with future changes in the ILS working practices.

As ADS is a new technology there is very little information on how to programmatically interface with it, and currently no publicly available systems to look at for help. There are still currently no generic web based systems that integrate with ADS, even Microsoft are currently only in the beta stages of creating a web based ADS solution. The project website is a first generation solution of its kind and provides significant benefits over older deployment solutions.

7.3 Critique
There were a number of difficulties encountered whilst creating the website, mostly due to the complex nature of the work. Despite this, the website code was very stable, and error free, due to the extensive testing that took place and my continuing improvement at programming with C#. Although Microsoft is correct in saying Windows Management Instrumentation (WMI) can be used to administer an enterprise environment, it is not simple to implement. Technologies are described as working together in harmony. In reality, integrating different technologies requires a lot of additional work, e.g. running an ADS job through C# code using WMI.

The main drawback of the project website is the problems with the flow of information when pages are submitted. Due to the difficulty of the task and the language chosen, there was no efficient way of passing the data. Hence, the user was limited to five tasks per job and four tasks per configuration. Despite these difficulties, all of the information is passed and displayed correctly.

7.4 Project extensions

Implementation of secondary user requirements
The easiest way to improve the website would be to provide more of the functionality that the user requested, e.g. to be alerted by e-mail when a configuration had been successfully applied.

Non-linear configurations
Currently the website only allows tasks to be run sequentially. The website could run non-linear configurations with the addition of a function that could determine the new positions of the jobs, no major code changes would be required. Figure 7.1 shows the current linear configurations and a potential non-liner configuration.

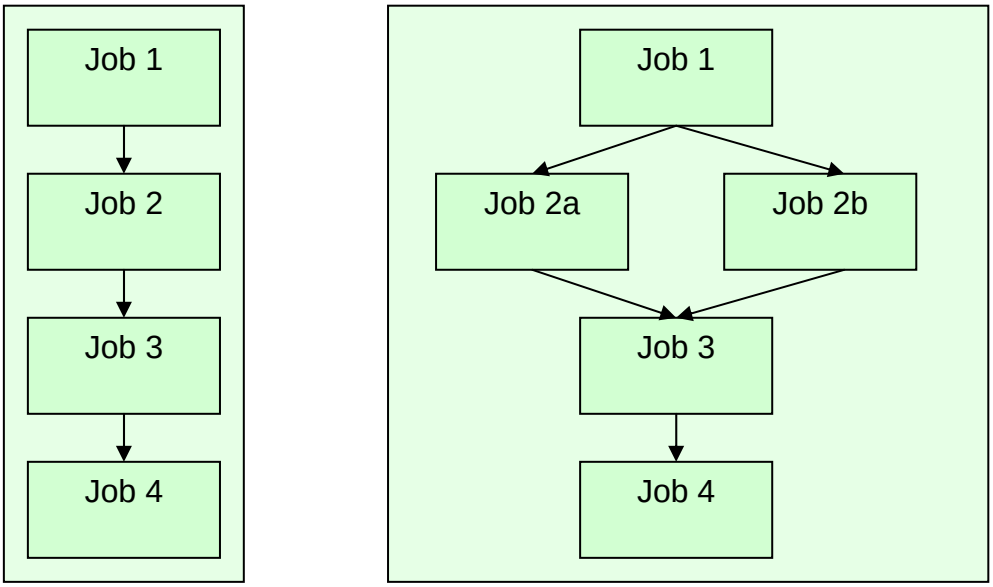


Figure 7.1: Linear and non-linear configurations

Future planning of configurations
As explained in Chapter 4, the website does not allow users to select a computer that are already in use to ensure they are not accidentally reformatted. This could be improved by allowing users to select the computers, but not allowing the configuration to be applied.

Further integration with ADS
Although the website integrates with ADS, it was designed as an extension to the existing ADS management program rather than a replacement. By fully integrating the website with ADS the website could replace the ADS management program altogether and allow full management of the ADS server remotely. This would be difficult due to the lack of documentation.

7.5 Conclusion

I am very pleased with the final outcome of both the website and report for the project. Although I am a very competent programmer, having to learn a new language and create a complex program in a short amount of time was challenging. Despite this, the users and I think the website is of high enough quality to be used in a production environment. The lack of documentation meant that trial and error had to be used at the start of the project to figure out how to interface with ADS, although once these problems were overcome the website worked well. All the tools chosen were also suitable for the project, and despite my prior lack of experience with C# it was a good choice of language as it simplifies integration with other Microsoft technologies more than a language like PHP would. Additionally, it extended my knowledge to include another programming language, and along with the other technologies I have used, such as ADS, WMI and XML, I have learned a great deal in addition to what I had previously been taught.